Vol. XXX No. 2 — PSYCHOLOGICAL REVIEW PUBLICATIONS — Whole No. 135 1921

THE
Psychological Monographs

STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF CHICAGO

The Influence of the Time Interval Upon the Rate of Learning in the White Rat

BY

JOSEPH U. YARBROUGH, Ph.D.
Professor of Psychology, Southern Methodist University

PSYCHOLOGICAL REVIEW COMPANY
PRINCETON, N. J.
and LANCASTER, PA.

Agents: G. E. STECHERT & CO., London (2 Star Yard, Carey St., W. C.)
Paris (16 rue de Condé)

PRINCETON
UNIVERSITY
PRESS

Acknowledgments

The experiments herein reported were carried out under the direction of Dr. Harvey A. Carr of The University of Chicago who has been unsparing in suggestion, supervision, and criticism. To him I wish to express my sincerest gratitude for his unwearying kindness and interest.

My thanks are due Professor James R. Angell, Dr. W. S. Hunter, and Dr. Clarence S. Yoakum for their thorough and stimulating instruction. My initial interest in Animal Psychology is due to my contact with the enthusiasm and scientific ability of Dr. Hunter.

For helpful suggestions I am indebted in particular to the work of Wylie; in general, to those other investigators whose work is cited in this report.

Acknowledgment is also due Mr. J. Hall Sheppard, a graduate student in the University of Texas, for assistance in the early training of some of the animals, and to Mrs. Yarbrough for assistance in preparing the manuscript.

Jos. U. Yarbrough.

University of Chicago,
Feb. 25, 1920.

TABLE OF CONTENTS

I.

Introduction

The experiments reported in this monograph[1] are concerned with three closely related problems in the field of animal psychology: 1) The influence of the time interval upon the rate of learning. The animals were divided into groups, and the terms X and Y were presented in a temporal relation to each group. The comparative number of trials necessary to establish a given strength of functional connection constitutes the measure of the relative efficacy of the several modes of presentation. 2) The readiness with which a given temporal association will function backward, and the most effective time interval for this functioning. The terms X and Y were here presented in the order Y-X, but in the test experiments they were required to function in the normal order X-Y. 3) The claims of the rival thories of simultaneous and successive presentation in relation to the rate of learning. The animals were required to associate two factors, X and Y. To one group the terms were presented simultaneously; to the others, successively.

The nature of the present experiments may be further set forth by additional explanation of the problems under consideration. The various statements made in the modern texts on general psychology indicate that simultaneous or successive presentation is regarded as an essential condition for the formation of an effective association. And by successive is meant *immediate* succession; *i.e.,* the two experiences must be in temporal contact with each other. Our aim is to separate these terms by a certain interval and observe its influence upon the rate of learning the association when the terms are presented in the forward and in the reverse order. Those who hold to the theory of simul-

[1] This research was begun in the Psychology Laboratory of The University of Texas in October, 1918, and continued until the following June, at which time the work was transferred to the Psychology Laboratory of The University of Chicago.

taneous association would have us believe that association cannot be formed unless the facts or objects associated be experienced simultaneously. They recognize the fact that in everyday life things are associated which succeed each other in time, but they account for this on the assumption that "with the cessation of the actual mental experience the nervous excitation is not abruptly finished but continues, gradually dying away."[2] The second factor of the association, then, coincides in time with this "gradually-dying-away" nervous excitation of the first, and it is due to this simultaneity that the association of the two factors is formed. The rival theory of successive association, based upon the hypothesis that the range of consciousness is not wide enough to attend to two things at once, denies the possibility of association between two factors simultaneously presented. Those who hold this theory say that although the two factors are apparently presented simultaneously they are in reality successive experiences, since the attention is constantly vacillating between the two. If successive association is correctly explained by the simultaneity of the succeeding experience with the after-phase of the preceding one, the data here presented show to a certain extent the duration of this "akoluthic" phase and its rate of diminution.

Although our prime interest is in the first of the problems listed above, it was found both practical and profitable to gather data on the second and third. Very little work on the main problem has been reported either in the field of animal or of human psychology, hence it is on this point that these experiments will probably have their greatest significance. The second, likewise, has received scanty attention as yet. The third problem, on the other hand, has been the subject of considerable experimentation, although but little of this investigation has been in the field of animal psychology. It is our purpose to present data upon these timely problems, with especial emphasis upon the question of the influence of the time interval in successive association upon the rate of learning in both its backward and its forward directions.

[2]Semon, Richard, "Die Mnene," 2te Auflage, Leipzig, 1908.

II.

Historical Section

The purposes of the present historical section are: 1) To bring together for critical consideration all the data reported up to the present time on the rate of learning in successive association; 2) To present a brief critical review of the experimental literature upon the subject of simultaneous and successive presentation in association; 3) To examine all data now published on the strength of function of association in the backward as compared to the forward direction; 4) To show that the evidence is inconclusive because of its scantiness and, in some cases, its general character. Due to the fact that in some of the experiments reviewed more than one of the above-named issues is discussed, it was deemed expedient to present the full report in each case rather than to attempt presentation by topics. Criticism and discussion have in some cases been deferred to the Theoretical Section.

Bigham[3] (1894) was among the first to investigate these questions. For subjects he used five college students of an average age of 24; for material, series of varied numbers and colors (separate or in mixed series) mounted on cardboard 3½ cm. in size. Five simultaneous series were used and five successive. In every respect the series were alike save in the manner of presentation. The length of the series consisted of either 10 or 20 presentations. A 40 second period was allowed for each series, 20 simultaneous presentations being made in this period, and, in the successive series, two seconds being allowed for each of the 20 cards. By this method the exposure time was two seconds, whether the cards were presented simultaneously or in succession. The subjects were asked to use no memory aids in the learning. After a given series had had its due presentation the subject immediately arranged his colors or numbers in the

[3] Bigham, J., *Psychol. Rev.*, 1894, Vol I, pp. 34-38.

order of the presented series as it was recollected. He saw the series but once. Obviously, only the visible series gave a basis for comparison, and in these Bigham found that for the simultaneous series the percentage of error for the five subjects ran: 13.6, 9.8, 15.3, 17.9, and 15. In the successive series the corresponding percentages of error were 18.5, 23.3, 16.6, 24.1, and 21.6. The averages for the two series were 14.3 percent and 20.8 percent for the simultaneous and the successive, respectively. Hence, he concludes: "With each observer the memory was stronger for the simultaneous than for the successive presentations."

Bergstrom[4] (1907) performed a series of experiments patterned after the work of Ebbinghaus. Three subjects were each required to memorize 12 lists of nonsense syllables, 12 syllables to the list, for each of four days. Each syllable was exposed to view for a period of 82σ, and a given time interval was allowed to elapse between the successive exposures of the syllables. The syllables were to be pronounced but once at the time of exposure, and after four repetitions of a list a recall test was given. In this test a written reproduction was made and the amount memorized was gauged by the number of errors made. The intervals between the exposures were 302σ, 686σ, and 1454σ, and the average number of errors was, respectively, 10.3, 8.9, and 7.5. By increasing the interval between exposures the number of errors was decreased. This fact is at variance with the assumption that a nervous impression begins to fade soon after it is received and gradually dies away, and must be explained by the greater strength either from the clearer original impressions or perhaps by other factors which are favored by a longer time interval.

Again, 30 subjects were used by this same experimenter, and lists of 10 words and lists of 10 letters, presented orally at a metronome-controlled rate, were used as material. The time intervals between presentations here were .5, 1, and 2 seconds. One presentation was made for each list, and the errors made in

[4] Bergstrom, J. A., *Amer. Journ. Psychol.*, Vol. XVIII, pp. 206-238.

immediate written reproduction again tested the amount memorized. For the three intervals the average percentages of error were, respectively, 51.12, 36.52, and 23.9 for the word lists, and 44.09, 52.65, and 38.44 for the letter lists. In both, the amount learned increased with the lengthening of the interval. Bergstrom concludes: "The effect of increasing the interval is greatly to decrease the number of errors. . . . Indications are that an interval longer than any employed would have still further reduced the errors."

Wohlgemuth[5] (1914) reports an experiment the purpose of which, as he states it, is 1) "to decide by experiment, if possible, between the claims of the rival theories of Simultaneous and Successive Association," and 2) "to investigate the influence of the closeness of connection between the members presented simultaneously." He used eight subjects, whose age and qualifications were undefined. To them he gave a series of tests consisting of pairs composed of a colored field (cardboard) followed by a black shape mounted on a white ground, or vice-versa. The exposure was timed by a Müller memory apparatus, a certain definite period of exposure thus being given each card. Obviously, under such conditions the simultaneous pair would have just the same period of exposure as each member of the successive pair. He found the successive mode of presentation superior to the simultaneous, but accounted for the difference on the basis of the unequal exposure time for each pair of stimuli. To overcome this defect two groups were formed: in the first, only half the number of exposures was given in the successive series, while each member of the pair was exposed for the same length of time as the pair of simultaneous stimuli—*i.e.*, the rate of the memory apparatus remained the same; in the second, the same number of exposures was given in both series and the same time given each pair, but only half time was given each member of the successive pairs—*i.e.*, the apparatus was set to work twice as rapidly in the successive series as in the simultaneous. Wohlgemuth finds that in the first group the average scores were 35.5

[5] Wohlgemuth, A, "Simultaneous and Successive Association," *British Journ. of Psychol.*, VII, 1914-15, pp. 434-452.

for the simultaneous and 33.2 for the successive; in the second group, 36.8 and 34.4, respectively. Hence, he concludes: 1) "The simultaneous experience is more favorable for the learning of pairs than the successive experience." 2) "All associations are due to simultaneity or simultaneity of the succeeding experience with the akoluthic phase of the preceding experience."

On the whole, Wohlgemuth's article is far from convincing. It seems that his evidence is insufficient to warrant such positive statements, and one is inclined to agree with Froeberg[6] in his criticism of the work. Froeberg says that Wohlgemuth's method of presentation must be rejected, but that even if this might be admitted "no safe conclusion could be drawn from the results because the differences in favor of simultaneity are in every case less than the P. E., and in five cases out of sixteen they are negative." Froeberg calls his own investigation an "attempt to repeat Wohlgemuth's experiment with the objectionable features removed." He used psychology students for subjects, and had them memorize series of five pairs of syllables. Each term of the pairs was exposed for a period of 1/3 of a second, and the time between the terms varied from 0 to 5 seconds. The interval between the successive pairs was a constant. The recall came 10 seconds after the last presentation (each series having been presented twice), and was conducted by presenting the stimulus syllables in a new order and requiring the subjects to supply the missing member of the pair. As usual, all memory devices were barred during the learning. The average percentages of correct response for the group of seven subjects were 61, 49, 45, 48, 51, 49, and 49 for the simultaneous and continuous presentations and the intervals of 1, 2, 3, 4, and 5 seconds, respectively—a finding which would indicate that the difference between the simultaneous and successive series is small, and that in successive presentation the length of the time interval is not effective. The simultaneous exposure yielded better results in every case, however, and the average difference of 12 percent in its favor seems significant. Froeberg does not think

[6] Froeberg, S., *Psychol. Rev.*, 1918, Vol. XXV, pp. 156-163.

that this slight superiority of simultaneous presentation necessarily proves the theory of simultaneity, but would explain it by a "tendency to articulate and combine the simultaneous syllables into a single word." From the introspection of his subjects he found "essential agreement on three points: 1) that simultaneous exposure taxes the attention more than successive, 2) that there is a persistent tendency toward articulation in the simultaneous series, and 3) that when in successive association there was an appreciable interval between the stimuli, the first would remain in consciousness, though with varying degrees of intensity, until the second arrived."

In order to eliminate this persisting memory image during the interval between the two stimuli in successive presentation the experiment was repeated with a group of four subjects and with the added condition that the subjects should read numerals presented to them during the intervals between the terms of the pairs, a device calculated to prevent memory survival of the first term during the interval separating it from the second. In this test the average percentages of right response for the simultaneous and continuous presentations and the time intervals from one to five seconds were 54, 45, 34, 36, 40, 24, and 22—*i. e.,* the rate of learning decreased with an increase in the length of the interval when a new activity was interpolated. This decrease in the rate of learning is distinct though irregular. From these data and the statement by each of his subjects that "the reading of the numerals effectively and completely obliterated the memory image of the preceding syllable," he concludes that association may still be formed between two experiences where the first has already passed out of consciousness when the second one appears. This is in contrast with the findings of Bergstrom.

Since Wohlgemuth had rejected nonsense syllables as improper material for the study of association, Froeberg formed another group of subjects to which he presented colors and letters of the alphabet. Other details were the same as in the previous experiments. He found under these conditions that the successive was superior to the simultaneous mode of presentation. This

finding in the data of the first group led him to the conclusion that when the material used is such that it forms an organic unit or can be attended as a unit, simultaneous presentation is preferable; when such that this is not possible, successive presentation is the better.

Chamberlain[7] sought to ascertain the effect upon the power of recall when a number of objects were displayed 1) singly and 2) three together. For subjects he used 60 pupils each from the third, fifth and eighth grades. By means of a circular disc of wood certain objects were exposed in fixed order for a given length of time. In the first tests these objects were exposed three at a time; in the second, one at a time. The two modes of display were never used with the same subject. One minute was allowed for the observation of 15 objects. In the first tests each object was exposed for nine seconds, while in the second series three seconds were allowed each object. It is obvious, then, that although one minute was given in both cases for the observation of the fifteen objects, the exposure time per object was unequal. The immediate recall was tested in every instance by having the pupil recall at the close of the experiment all the objects he could remember. These objects were listed by the experimenter in the order recalled. The subjects were also provided with circular sheets of paper and asked to arrange the objects thereon as remembered from the circular disc. The author concludes that both recall and arrangement of objects are stronger when the objects are seen three at a time than when shown singly, a conclusion scarcely warranted by the insignificant percentage of difference between the two modes of presentation. The average number recalled by the three grades when the objects were presented singly was 9; when presented three at a time, 9.37.

In the human field investigations on the direction of association have been made by Ebbinghaus, Müller and Schumann, Müller and Pilzecker, and Wohlgemuth. In each investigation

[7] Chamberlain, A. H., "A Memory Test with School Children," *Psychol. Rev.*, 1915, XXII, 71-76.

memory material was used. Ebbinghaus[8] employed the relearning method and found a strong tendency for an association to function in the backward direction, but its strength was never equal to that of the forward tendency. Müller and Schumann[9] using practically the same method, confirmed these results. Later, Müller and Pilzecker,[10] using the method of recall, found that when pairs of syllables had been learned as trochees and the first syllable was shown, in 50 percent of the cases the second syllable was reproduced, while when the second syllable was shown the first member of the pair was recalled in only 38 percent of the answers. Here a backward tendency is shown, but it is of less strength than that of the forward direction.

Working in the Psychological Laboratory of the University of London Wohlgemuth[11] experimented rather extensively, varying both method and material. He had come to doubt the universal application of the results obtained by the use of nonsense syllables in the study of memory, and to verify the results he used colors and diagrams. To make a further check on his findings he used syllables in exactly the same way as he did colors and diagrams. With five of his subjects the forward tendency was the stronger, and with two the backward and forward tendencies were about equal in strength. He concludes that the forward tendency is the stronger when articulation is used in memorizing, but that the two tendencies are of equal strength when articulation is prevented. Just in proportion as the motor element approaches complete elimination do the results indicate an equal functioning strength in both directions.

In the field of Animal Psychology there is, as we have said before, very little work reported upon the problem. Carr[12] is

[8] Ebbinghaus, "Über das Gedächtniss," Leipzig, 1885.

[9] Müller and Schumann, Experimentelle Beiträge zur Untersuchung des Gedächtnisses," *Ztsch. f. Psychol. u. Physiol. Sinnesory,* 1894, VI.

[10] Müller, C. E., and Pilzecker, A., "Experimentelle Beiträge zur Lehre von Gedächtniss," *Ztsch. f. Psychol.,* 1900, Ergänzungsbd. 1.

[11] Wohlgemuth, A., "On Memory and the Direction of Association," *Brit. Journ. of Psychol.,* 1912, Vol. V, p. 447.

[12] Carr, H. A., "Length of Time Interval in Successive Association," *Psychol. Rev.,* Vol. XXVI, pp. 335-353.

the chief contributor. He reports a series of brief but suggestive experiments. First, he reports three short experiments, all bearing upon the subject of the influence of the time interval. White rats were used in each of the experiments, and the same problem box. The problem for the rats was to learn to choose between two pathways to a food-box in a given temporal sequence, R, L, R, L, etc. In case of incorrect choice the entrance to the food-box was barred. Always the day's work began with pathway R. Between the successive runs of a day's series the rats were allowed to eat for a definite time interval. In the first experiments three groups of eight rats each were used, and the intervals for the groups were 15, 25, and 35 seconds, respectively. The results indicate no essential differences between the groups in the initial stages of the learning, and, indeed, no essential differences throughout for the 15 and 35 second intervals. The group tested on 25 seconds interval manifested a quite rapid rise from the 1000th to the 1200th trial. This, however, is an inconclusive finding, as other factors than the time interval may have influenced the result. The group was too depleted, unfortunately, to permit of further continuation of the experiment. In a second experiment three groups, six rats each, were tested for intervals of 5, 10, and 15 seconds, respectively. In this test the entrances to the pathways R and L were alternately blocked so that errors were impossible. Test series in which the pathways were left open were interpolated every fifth day. Thus the rats were forced to choose between the pathways and the learning was measured by the number of correct choices made in these test series. To quote the results: "The group difference is not very significant, but the results indicate that 10 seconds is a more favorable interval than 15 seconds." In brief, he admits that his findings are inconclusive as regards the influence of the time interval upon learning, but states that they do prove that "an association nexus can be established over a considerable interval of time," and that they make possible the acceptance of the hypothesis of direct connection between the factors in successive association.

Carr and Freeman[13] report an experiment upon the problem of simultaneity vs. succession, and upon backward vs. forward direction in forming an association. A box with zigzag runways was used. In preliminary tests rats were taught to run these pathways in order to obtain food. Afterwards in 80 per cent of the trials the door from the chosen pathway into the food-box was closed, and the rats were forced to retrace and run the opposite pathway in order to reach food. At this stage the rats were divided into three groups for the purpose of testing the formation of an association between an auditory stimulus, buzzer, and the act of turning in response to the closed door. With one group the buzzer was sounded just as the rat was in the act of turning—simultaneously with the response to the closed door. With another the sound was given at a definite point, P, approximately one second before the door was reached. The third group was given the sound at point P in the return pathway approximately one second after the rat had turned around from the closed door. Test series wherein the sound was given at any point within the pathway were used to test the formation of the association. It was found that "successive presentation of the two terms constitutes a much more favorable method for their association than does simultaneous presentation." The groups on backward association showed slight evidence of learning when the experiment closed. These results are extremely suggestive, but some points of weakness should be pointed out: 1) The time interval between the two terms to be associated was not constant. Those who are acquainted with the behavior of white rats would not expect them to traverse the distance from a point, P, to the closed door at the same speed each time. 2) The buzzer which was the source of the sound stimulus was in contact with the maze. The animal may, therefore, have been responding to a kinaesthetic or cutaneous sensation and not to sound at all.

Watson's experiments also contribute data in the comparative field bearing upon this problem of backward association. He tested white rats for their ability to learn a maze backward after

[13] Carr, H. A., and Freeman, A. S., "Time Relationships in the Formation of Association," *Psychol. Rev.*, Vol. XXVI, p. 465.

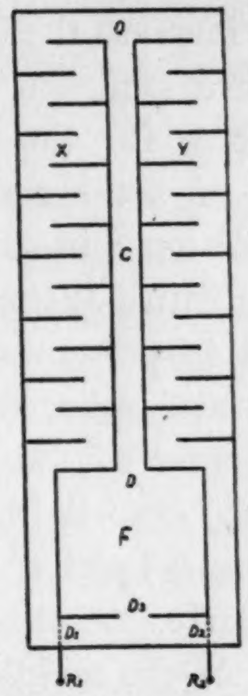
having learned it in the forward direction. These data are not considered conclusive, for all who have trained rats know that considerable retracing is done while mastering a maze.

Summary. 1) The majority of the experimental data reviewed favors the simultaneous mode of presentation. 2) In regard to the time interval, Bergstrom is convinced that with the increase in the length of the unfilled time interval the amount learned increases. Froeberg is of the opinion that an increase in the length of the time interval increases the difficulty. 3) All investigators have found a tendency toward backward association—a tendency varying in strength, but seldom equal to and never stronger than the forward tendency.

III.

Apparatus and Method

The ground plan of the problem box used in this experiment is shown in Fig. 1. The outside dimensions are 89″ x 30″. The box is constructed of ¼″ soft pine, and is 6″ deep. All runways



Ground Plan of Apparatus

Fig. 1

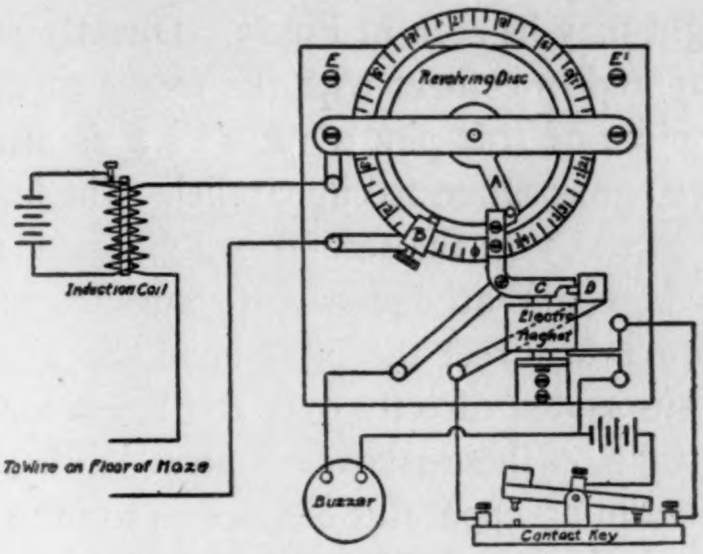
and doors are 4″ wide and 5″ deep. The doors are made of very thin metal and are so hung that they may be opened and closed without appreciable noise. Especially is this true of doors D1 and D2 which are controlled by rods R and R1. The entire surface of the box is painted black. The food-box F is 16″ x 20″ and is the only portion of the box not covered with glass. The entire floor of the maze in front of the food compartment, with the exception of the long runway from the center door D, to the point O, is laid with No. 20 copper wire at ¼″ intervals. By pressing a contact key a current from three dry cells is sent through an induction coil which sends an induced current over the entire system of wire on the floor of the maze. The strength

of the current passed over these wires is so controlled that the animal never becomes frightened by a severe shock.

This box was developed from the one used by Carr and Freeman[1] in their experiments. The following improvements were made in the construction of the present box: 1) The glass cover was extended so that the animal is not required to come out in the open until it enters the food-box. 2) There is but one door to the food-box. 3) The source of the stimuli is above the glass cover, making contact with the animal impossible. Furthermore, it was necessary to increase the box in length and number of compartments to secure sufficient time between the point of choice and the food-box for the presentation of the two stimuli with an interval of six seconds between them. The animals seldom made the distance in so short a time, but in their most rapid responses the entire distance was traversed. The additional apparatus used in presenting the pair of stimuli in certain temporal relations are rather tediously described below.

About 18″ above the center of the box a light of very low candle power is suspended. The light from this source is just sufficient to enable the experimenter to see the animal move through the maze. Similarly, an electric buzzer is suspended 10″ above the glass cover of the middle portion of the box and connected with the batteries and the timing apparatus as is indicated in Fig. 2. The timing apparatus is, in turn, attached to a Zimmerman kymograph by screws E and E[1] in a way shown very well in Fig. 3.. The revolving disc upon which the arm A rests is in direct connection with the shaft of the kymograph, which turns it around the dial at any speed desired. The dial is graduated so as to read seconds, half seconds, and quarter seconds, when the kymograph is adjusted at the rate of one revolution for every 15 seconds. Each of the numerals, therefore, represents the number of seconds necessary for the arm A to move from the zero point to the respective numeral as it appears on the dial. The contact B may be moved along the dial and firmly set at any point by the thumb screw. The arm A is not

[1] Carr, H. A., and Freeman, A. S., "Time Relationships of Association," *Psychol. Rev.*, Vol. XXVI, p. 465.



TIMING APPARATUS

FIG. 2

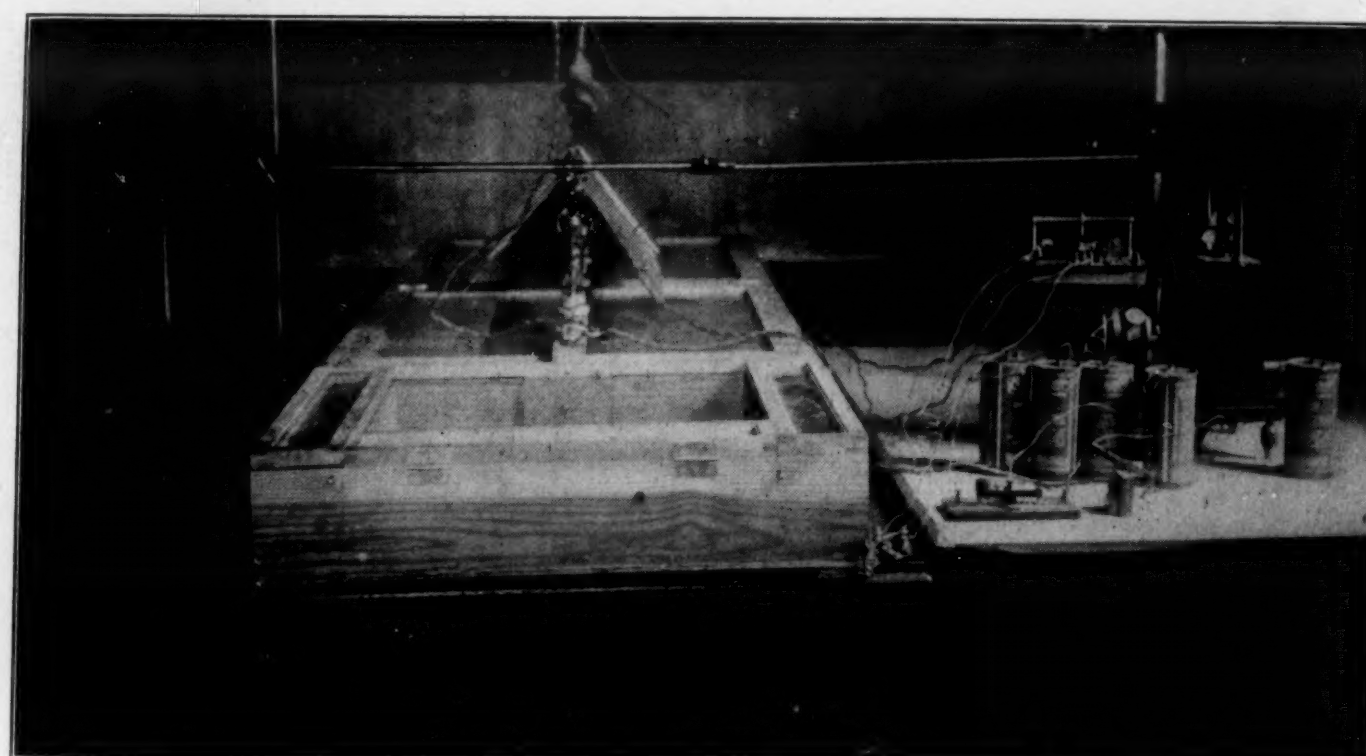
fastened to the shaft of the kymograph, but is carried along by friction on the large revolving disc. If the circuit is closed and the electro-magnet pulls the lever C into place, the arm A is held in the position shown in the drawing. The strength of the magnet is great enough to overcome the friction on the revolving disc.

By pressing the contact key the circuit of the electro-magnet is broken, and is closed on the electric buzzer. This presssure not only gives the sound stimulus, but it also releases lever C, allowing arm A to be carried along with the revolving disc and to pass over contact B, which closes the circuit through the induction coil and the system of wires on the floor of the box. When the contact key is released the current again flows through the electro-magnet, attracting lever C, which keeps the arm A from moving when it again reaches that point. Thus the apparatus automatically completes the process, and after 15 seconds it stands ready for a repetition at the will of the experimenter. The friction contacts at D and B are so constructed that the current is broken at the end of one-half second. Each stimulus is, therefore, given for this period of time. By this apparatus it is possible very accurately to present two stimuli in a certain definite temporal relation to each other.

With certain groups of animals light was used as one of the two terms to be associated. The new apparatus added for pre-

senting the light may be seen in Fig. 3. Directly above the long central runway and in contact with the frame of the glass cover of the box a piece of soft pine 1″ x 2″ - 4′ is attached, and to it is affixed two lamps connected in parallel. The first lamp is 18″ from the end of the box; the second is 22″ nearer the food-box. National Mazda 100 Watt lamps are connected on a 115 Volt circuit. In order to direct the light upon the zigzag pathways a reflector is suspended directly over the lights and so adjusted that the light falls on these runways only. With proper electric connections the timing apparatus enables us to present sound and light in a certain known temporal relation, just as the buzzer and pain were previously presented.

The method of procedure may be described as follows: The animal to be tested is put through the door D from the food-box F into the central runway C. He is required to go up to point O and turn either to the left or to the right and return through the zigzag pathway X or Y, through the door D1 or D2, and through D3 into the food-box F where he is given food. It is of little interest in these experiments whether the animal turns to the one side or the other, or to one side altogether, for the problem is in no way affected by the alley chosen or by position habit. The alley chosen in no way determines what is to follow. Seven times out of ten trials the animal is given an electric shock in the return zigzag runway; no shock is given in the three remaining trials. This shock may be given at any point along the runway, lasts for a period of one-half second, and is given only once during the trial. The problem here is to learn to turn around for pain or to go on in case no pain is given. If pain is given and the animal does not turn around but goes on toward the food-box he finds the door at the end of the alley closed. Thus, for example, if the door is D2 he must, to gain entrance to the food box, run back through the zigzag alley Y, pass the point O, and approach through the alley X and the door D1. When no pain is given the door of the alley selected is always open and the animal enters the food-box direct. The problem here may, therefore, be thought of as an association



Perspective of Apparatus

Fig. 3

between a closed door and an electric shock, and farther on in this report it will often be referred to as learning the negative response to pain.

From the above conditions it will be noted that no stimuli are given in 30 per cent of each series of trials. This, together with the fact that chance and position habits are of so little significance in the solution of the problem, led us to hold a rather rigid standard as to the number of trials and the percentage of correct reactions to be required of all animals. No animal was, therefore, considered to have mastered the problem until he had made 90 per cent correct responses on the last 100 trials. All animals used in the experiments reported below were first required to learn this negative response to pain. When this was accomplished an electric buzzer was introduced, by means of the timing apparatus, in a certain definite temporal relation to the electric shock, pain. The animals were divided into groups and each group was set to work upon the problem of transferring this negative response from pain over to buzzer, but each group worked with a different time interval. To some groups the stimuli (buzzer and pain) were presented in a forward direction; to others, in a backward—*i.e.*, some groups received the buzzer followed by pain, others, pain followed by buzzer. In the test series the order was always buzzer followed by pain. The problem in each group is to learn to respond to the sound stimulus as they have been responding to pain. It is a transfer of response from pain to sound over certain given time intervals. Continuous presentations and one, two, four, and six second intervals were studied. In the work with the first of the above groups special test series of 10 trials each were given after each 20 trials to determine to what extent the transfer had been made. In the remaining groups the time interval was sufficiently large to determine this without these special tests. The standard for mastery in each of these groups is the same as before, 90 per cent on the last 100 trials.

As the animals completed this problem they were regrouped and set to work on a third problem, but in the regrouping no

animal was changed from a group where the stimuli were presented in the backward to a group where they were presented in the forward direction or vice versa. The situation really remained the same with the exception of the changed stimuli—*i.e.,* the substitution of the response is now from the auditory stimulus to light instead of from pain to sound as before. The same time intervals were studied as before. As in the previous experiment, it was necessary to enter the special series of test trials only in the study of the first interval to determine the extent to which the transfer had been made at any given time. The same standard is required here as in other problems.

IV.

Experimental Results

1. *The Influence of the Time Interval in Successive Association upon the Rate of Learning.*—The experiments bearing directly upon this problem may be divided into two sets: A. Those in which the association was learned in the forward direction; B. Those in which the association was learned in the backward direction. Groups I to XII were tested in the first set and Groups XIII and XIV in the second. All the animals were of about the same age and health conditions. Twenty trials were given each day. To have mastered the problem the animal must have made not less than 90 per cent of correct responses over a period of five consecutive days, *i.e.,* 90 per cent on the last 100 trials.

A. Learning the Association in the Forward Direction.—Associations were made between stimuli from different sense fields. Two pairs of stimuli were used: a) auditory (buzzer) and pain (electric shock), and b) visual (light) and auditory. The auditory-pain experiments are presented first.

a) Association of buzzer with electric shock.—In order to secure comparative data upon the influence of the time interval between the presentation of buzzer and the presentation of pain, the animals, upon mastering the problem of negative response to pain,[1] were divided into groups, and each group was set to work to transfer this negative response from pain over to the buzzer. The sound was always presented before pain but in a different temporal relation to pain in each of the groups. Other factors remained constant for all of the groups. In addition to presenting the stimuli in immediate succession, *i.e.,* in temporal contact, presentations at intervals of one, two, four, and six seconds were made. In all, 38 animals were used.

1) Continuous presentation.—Group II was trained on buzzer followed by the pain immediately. The results of the work of this group are summarized in Table II.

[1] See division 3 of this section.

TABLE II

Animal	Trials	% Correct on Last 100
25	120	91
26	120	90
27	140	92
28	120	91
29	120	90
50	100	93
Average	120	91.1

A set of test trials was interpolated after each 20 trials of the regular series in order to measure the gradual growth of the association. The average number of trials necessary to master this problem was 120, but a study of the curve in Fig. 4 and the records of the individuals of the group show that after 60 trials some of the group held their record to and above the 90 per cent mark, and that after 80 trials no animal fell below this point.

2) One-second Interval.—Group III was used in these tests. The buzzer was presented one second before pain, to which they had previously learned to respond negatively. If the old response to pain was transferred to the sound stimulus, and the animals turned around for it, no pain was given. But if they failed to turn around to the buzzer and instead continued toward the food-box, the pain was given at the end of one second. Results are given in Table III. It was unnecessary to give the

TABLE III

Animal	Trials	% on Last 100
1	118	96
12	131	91
22	128	91
24	126	92
35	148	90
37	120	87
Average	128.5	91.1

special test series in this group in order to determine the gradual growth of the association, for if, in the regular training series, the animals failed to turn around before pain was given, the response was recorded an error: if they turned at the sound no

pain was given. These regular tests, therefore, show the gradual growth of the association if properly analyzed. The analysis of Table III is given in the curve presented in Fig. 4. Each point of this curve was determined by the average per cent of correct responses for the group in 20 trials of the regular training series. The growth of the association, as determined by the percentage of correct responses, is recorded for each 20 trials during the entire learning period.

The 30 per cent of trials in which no stimuli were given proved to be an excellent control for determining whether or not the animals had developed the habit of turning each time in the first alley selected, or were turning only when the sound was encountered. Without an exception they continued to the food-box during these trials. Very often they would proceed slowly and manifest hesitancy, much as the human does during a period of expectancy and uncertainty, but in no case did they turn around. The following conclusion is warranted: The turning response was transferred *from* pain *to* buzzer rather than to some other factor; 128.5 trials were necessary to perfect this transfer.

3) Two-second interval.—The two stimuli were presented to Group IV with an interval of two seconds. Again the special tests were omitted and the rate of of learning measured in the regular trials. Tabulated results for the group are to be found in Table IV. With the exception of Nos. 10 and 39 the individual differences are small. With No. 10 the association began early in the period, but it was very difficult for him to hold the percentage of correct response over a period of five days. Num-

TABLE IV

Animal	Trials	% on Last 100
10	316	92
11	210	91
21	166	92
23	211	90
38	203	93
39	269	90
Average	229	91.2

ber 39 was very slow in beginning the transfer, but when once started the percentage increased normally.

The gradual growth of the association in this group is obvious from the curve in Fig. 4. Each point of this curve represents the average for the group in percentage of correct response for 20 trials of the regular learning series. Although we had used the 30 per cent of undisturbed trials throughout these experiments, at the end of the work each animal was given a special series of ten test trials in which pain was withheld. In these tests the response was unaffected. The group required an average of 229 trials to reach the standard imposed.

4) Four-second Interval.—With Group V the sound was presented four seconds before pain. Seven animals were used in the group, and Table V gives their data. There are no marked individual differences, a gradual increase in correct responses being maintained by each animal, as is graphically shown in the learning curve in Fig. 5.

TABLE V

Animal	Trials	% on Last 100
4	236	94
13	265	92
16	240	91
19	187	91
40	228	93
41	216	94
52	269	91
Average	236	92.4

After the work was completed the special set of test trials was given with no effect upon the per cent of correct responses. The average number of trials necessary for mastery was 236.

5) Six-second Interval.—Group VI made the association over an interval of six seconds. Table VI shows the number of trials necessary to make the association and the standard of correct reaction reached. From the table and the learning curve in Fig. 5 it is possible to appreciate the general disturbance during the first 60 to 100 trials, as well as the gradual growth of the association. During this first period of learning the animals not only

ignored the buzzer, but also the negative response to pain often broke down.

TABLE VI

Animal	Trials	% on Last 100
43	229	92
45	226	91
46	217	91
47	224	90
48	274	90
49	280	93
51	288	89
Average	248.3	90.9

In other words, if the animal failed to turn for the buzzer he also often failed to turn for the pain and continued his course toward the food-box until he encounted the closed door. This same thing happened in all the groups but not so frequently as in this one. This common period of confusion prehaps accounts for the larger number of trials necessary for this group to master the association.

Summary.—The results for these five groups are brought together in Table VII. From these results the following con-

TABLE VII

Group	Time Interval	Trials
II	0 seconds	120
III	1 "	128.5
IV	2 "	229
V	4 "	236
VI	6 "	248.3
	Average	192.3

clusions are warranted: 1. Measured in terms of the number of trials necessary to learn the association, the difficulty of making the transfer of response does not increase uniformly for the increase in the length of the time interval between the two stimuli presented. 2. There is a disproportionate increase in difficulty when the interval is increased from one to two seconds. 3. There is practically no increase in difficulty when the interval

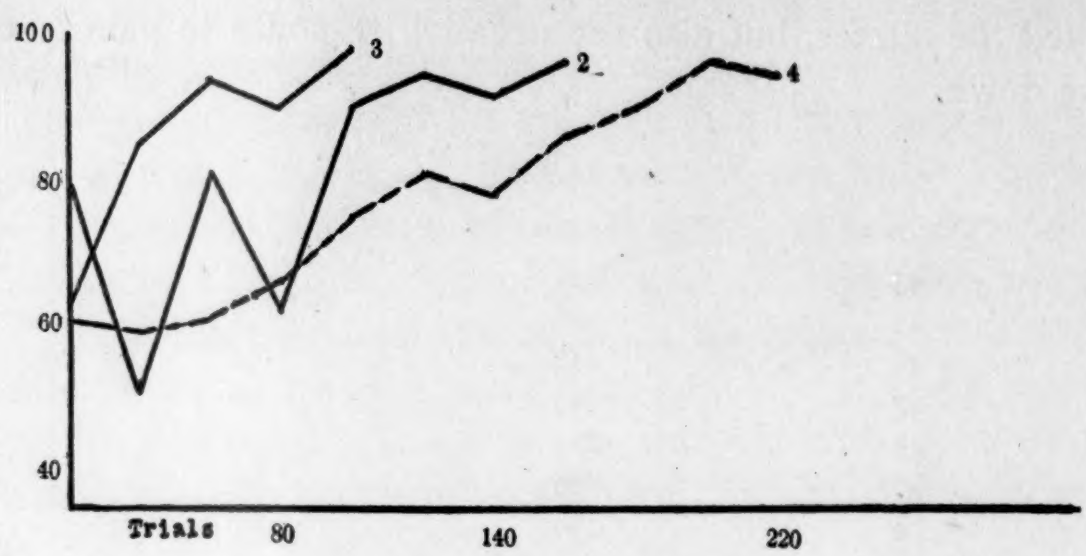


Figure 4

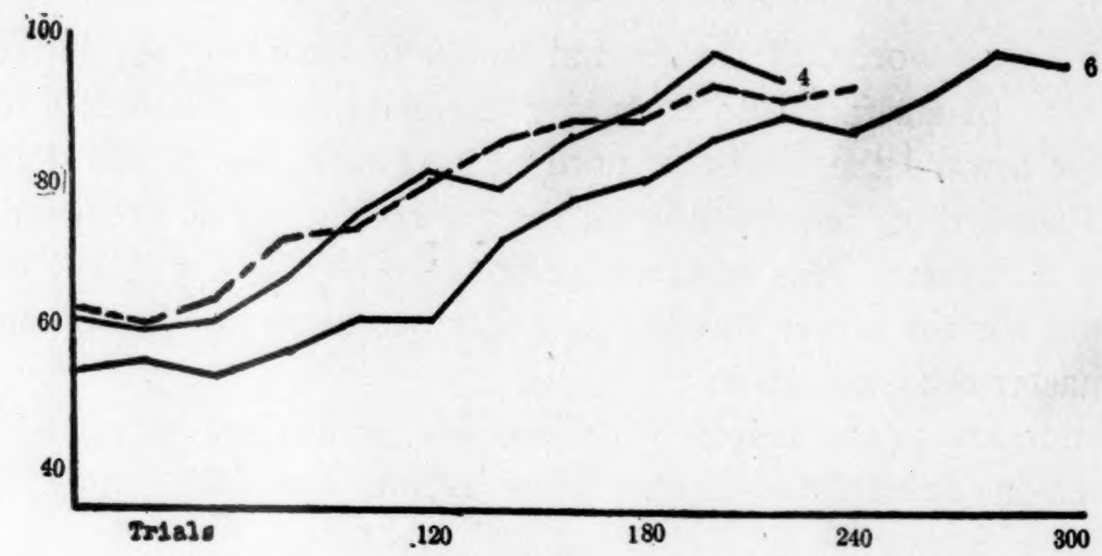


Figure 5

Curves 2, 3 and 4 (Fig. 4) are the learning curves for the Groups II, III and IV, respectively. Curves 4, 5 and 6 (Fig. 5) are the learning curves for Groups IV, V, and VI.

is increased from two to four seconds. 4. The six-second interval is more difficult than the four-second, but the increase in difficulty is not so great as from the one-second to the two-second interval.

b) Association of Light with Sound.—When the animal had made the association of sound with pain, the pain had in reality dropped out, and the animal responded to the buzzer whenever presented. To demonstrate the accuracy of this statement a special set of test trials was given at the end of the learning period in which pain was not given at all, and the percentage of correct response was not affected. It was possible, therefore, to

introduce another stimulus affecting still another sense at certain definite time intervals before the buzzer, just as the buzzer had been entered before pain in the groups previously reported. Light was selected for this new stimulus. By properly connecting the timing apparatus in the light circuit as described above, it was possible to present the two stimuli (sound and light) with a known time interval between them. The animals were regrouped and five new groups were set to work on learning to transfer their motor response from sound over to light. With the exception of the time interval, conditions were constant for all the groups. As before, experiments were made with continuous presentation and with one, two, four, and six second intervals. The 90 per cent standard was again adopted. In all, 24 animals were used on this problem.

1) Continuous presentation.—Here the problem was the association of light with sound when presented in immediate succession. The data for this group are given in Table VIII. One

TABLE VIII

Animal	Trials	% on Last 100
48	100	96
49	100	89
50	100	91
51	100	90
Average	100	91.5

hundred trials were given to each animal, but the test trials show that the association was complete at the end of 60 trials. The curve in Fig. 6 shows a period of fluctuation in correct response between the regular series and the test trials. After 60 trials in the regular series the curve remains almost uniform at 90 and above. This uniformity was reached in Group II at the end of 40 trials. A comparison of this curve with that of Group II, Fig. 4, indicates that the light and the buzzer offered a problem of practically equal difficulty with the sound-pain association in the first part of the period, but the transfer to light was more readily made. From a study of the individual records in the two groups it was found that under these conditions when ani-

mals once learn to respond to light they hold a more uniformly high record than when responding to sound. On the basis of the number of trials necessary to make the association it was easier for the animals to associate light with sound than sound with pain, when the two stimuli were presented continuously.

2) One-second interval.—The animals in Group IX made the light-buzzer association over a one-second interval. They had just transferred the negative response from pain to buzzer, and the new problem called for this response to be transferred to light, the latter being presented one second before the former. When the animal turned to the light, the buzzer was not sounded. Failure to respond negatively to light was recorded an error. Table IX gives the data for this group. No special test trials

TABLE IX

Animal	Trials	% on Last 100
37	160	94
45	140	92
46	140	94
47	140	93
Average	145	93.2

were given, the results of the regular training series being sufficient to show the rate of learning the association. The percentage is very low at the beginning of the learning period and increases rapidly, giving a positive accelerating curve. When compared with the learning curve for Group III, where all conditions are the same except the stimuli, two marked differences are found: 1) The percentage of correct response in the first 20 trials is considerably lower for Group IX; 2) no learning is indicated by Group IX until after 40 trials, while learning appears to have begun immediately with the other group. Under these conditions, 145 trials were necessary to transfer the negative response from the sound to the light.

3) Two-second interval.—To Group X the stimuli were presented with an interval of two seconds between them. The animals dropped low in efficiency in the first series, but when learning began the curve rose as rapidly as that for Group IX.

See data in Table X and the learning curve in Fig. 6. The problem for Group X differed from that for Group IV only in the matter of stimuli used, but there is a marked difference between

TABLE X

Animal	Trials	% on Last 100
13	160	93
16	180	90
19	160	92
35	180	93
Average	170	92

the curves for the two groups. In the Group IV curve is shown a period of no learning, followed by a brief plateau and a second period of gradual growth, which brings the record up to the standard. In contrast, the Group X curve shows a shorter period of no learning, followed by rapid progress. There are two possible explanations for this dissimilarity. First, it may be due to the previous training the animals in Group X had had in the problem of pain-sound transfer. Second, the pain-sound transfer may be more difficult than the sound-light transfer.

4) Four-second Interval.—The animals in Group XI were trained to associate light with the buzzer when presented with a time interval of four seconds. Table XI records the results.

TABLE XI

Animal	Trials	% on Last 100
4	160	92
23	140	93
38	160	91
39	160	90
Average	155	91.5

From these data and the curve in Fig. 7 one may see the rate of learning the association and the number of trials necessary to master the problem. There are no marked differences between the data of this group and those of Group X above. In each case there is a complete breakdown in the early part of the period followed by a period of rapid learning. With this group there

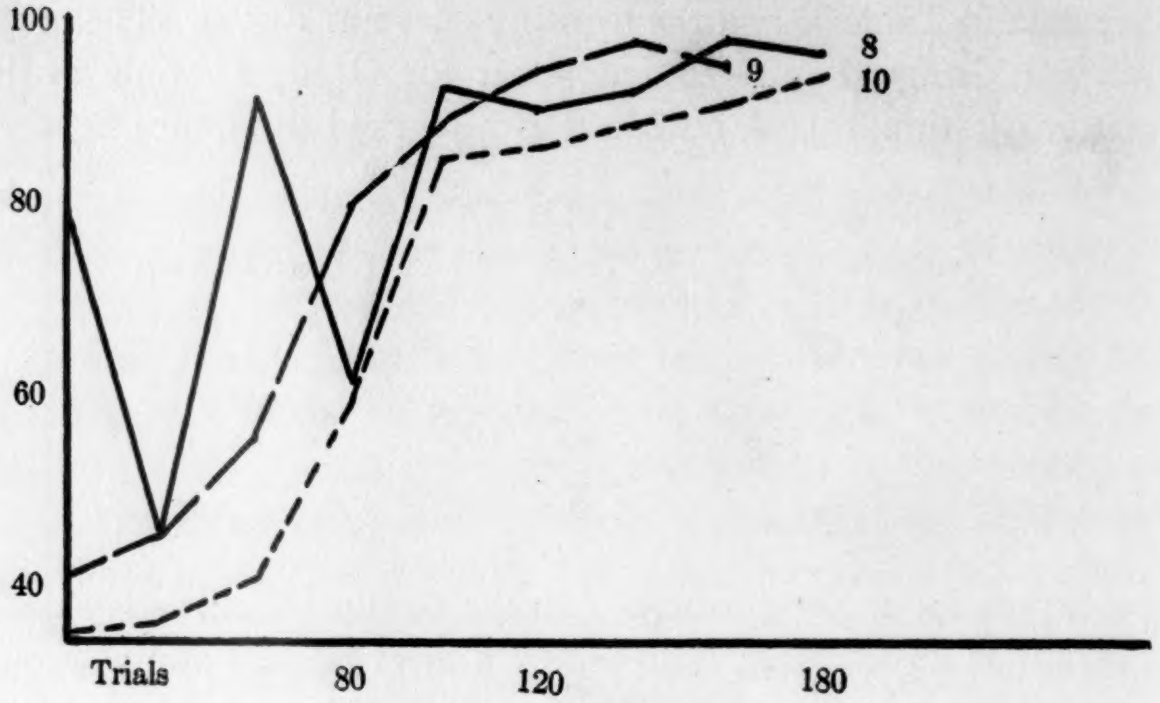


Figure 6

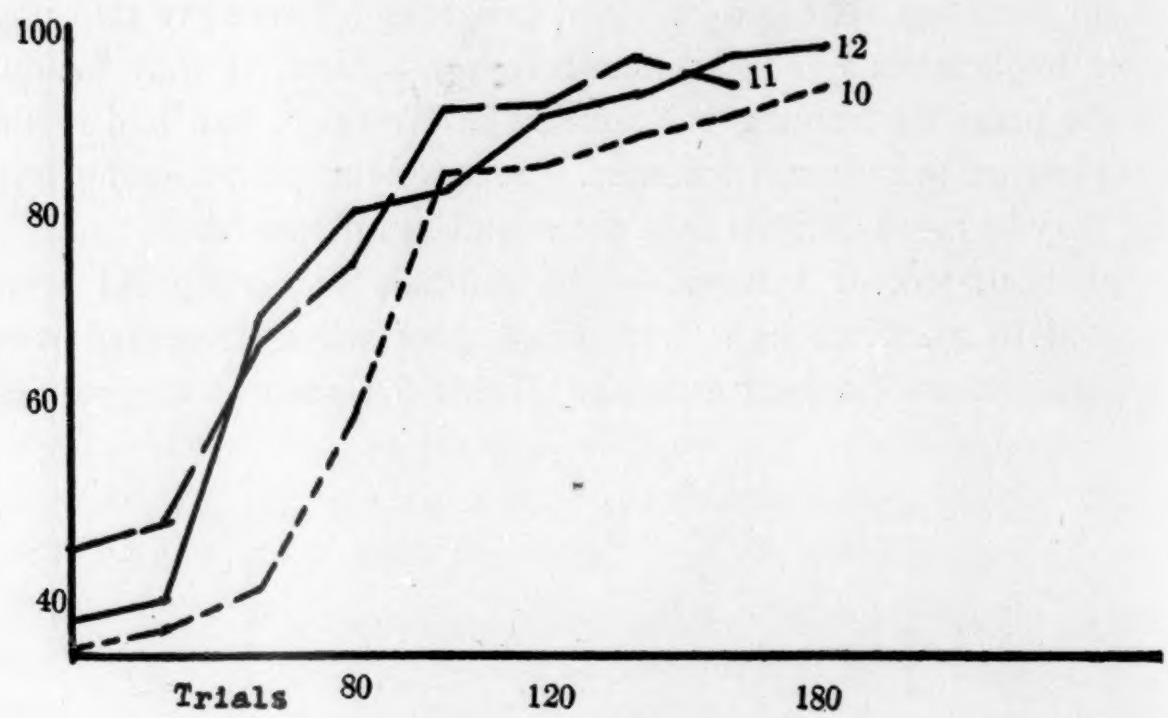


Figure 7

Curves 8, 9, and 10 (Fig. 6) are the learning curves for Groups VIII, IX, and X, respectively. Curves 10, 11 and 12 (Fig. 7) are the curves for Groups, X, XI and XII.

appears to be no increase in difficulty with an increase of the time interval from two to four seconds. But when compared with the data of Group V in which sound and pain were presented in the same temporal relation, two points of difference

appear. First, the breakdown in the beginning of the learning period is more marked in the latter. A percentage of 45 was made in this group, while in Group V an efficiency of 62 per cent was maintained. Second, the learning curve rises much more rapidly for Group XI. The percentage of increase rose from 45 to 95 in four series of trials, while in Group V the increase for the corresponding period was from 67 to 74 per cent. Seven days were required for Group XI to reach the 90 per cent mark of correct response. Previous training is an explanatory factor, but indications are that this difference is largely due to difference in the stimuli used. The data thus far gathered indicate that, other things being equal, it is more difficult for white rats of the type used in these experiments to associate sound with pain than light with sound.

5) Six-second Interval.—Group XII learned the association when light was presented six seconds before sound. In Table XII is given the data for this group. The association over this time interval required more trials than did that for any other group, but the difference is not great enough to be of significance. The curve in Fig. 7 will assist in showing the rate of learning. In form it follows rather closely the curve for Group XI—low at first, followed by a period of rapid learning.

TABLE XII

Animal	Trials	% on Last 100
1	160	91
10	200	94
11	180	92
12	180	95
Average	180	92.5

The effect of stimulus difference is shown by comparing this curve with that of Group VI. The curve for the former group begins somewhat higher, and instead of rising higher it first tends downward and later ascends, gradually reaching the 90 per cent mark after 180 trials; the curve for the latter exhibits a very brief period of no learning, followed by very rapid progress.

Summary: To enable the reader to see at a glance the results

obtained in each of these five groups the following table was constructed. From these data and the curves presented the fol-

TABLE XIII

Group	Time Interval	Trials
VIII	0 seconds	100
IX	1 "	145
X	2 "	170
XI	4 "	155
XII	6 "	180
	Average	150

lowing conclusions were reached: Judged on the basis of the number of trials necessary to make the association, the difficulty of the problem of transfer of response from light to sound appears not to have increased proportionately with the increase in time interval between the presentation of the two stimuli. Practically the same increase in difficulty is manifest in going from continuous presentation to the one-second interval as in going from the one to the two-second interval. The four-second interval, on the other hand, seems easier to master than the two-second but less easy than the one-second. The learning curves start low, go through a short period of no learning, and then rise rapidly in each group.

B. Learning the Association in the Backward Direction.—In reading the literature on the phenomena of association one is lead to the belief that psychologists generally hold to the conclusion that recall is predominantly in the forward direction. Some experimental data, however, indicate that an association will function backward as well as forward. Freeman found that "the formation of an association between a stimulus and a motor response by animals is exceedingly difficult and perhaps impossible when the stimulus is presented after the act has occurred." Since our method of procedure and experimental conditions were so different it was decided to include an examination of this point.

Two groups of animals (Groups XIII and XIV) were used in these experiments, the problem being the transfer of the pre-

viously learned negative response from pain over to the auditory stimulus (electric buzzer). The buzzer was given in each case after the pain had been given: to Group XIII it was presented in immediate succession; to Group XIV, with an interval of one second separating it from pain. Thus, in the latter case the two factors were presented in the backward order with a time interval of one second between them, *i.e.*, the sound stimulus was presented after the motor response to pain had been initiated and in some cases completed. All the animals were given, in addition to the regular training series, a series of test trials. The object of the training series was to establish an effective association between the turning response to pain and the auditory stimulus; the object of the test trials was to determine the degree to which an effective association had been formed. In these tests the procedure was the same as in the training series except that no pain was given. If the negative response had been transferred to the auditory stimulus, they should turn and retrace the path when the buzzer was sounded. A correct response consisted of an immediate turn when the auditory stimulus was presented, or of traversing the whole length of the path into the food-box in the 30 per cent of trials in which no stimulus was given. Progress was measured by the increasing percentage of correct response during the test trials. For in each group the established negative response to pain prevented the animals from responding to sound during the training series. They would most often have turned around or be turning around when the auditory stimulus was given. It is obvious, therefore, that the new stimulus which was to be associated with the turning response occurred after the act of turning had been initiated. A correct response in the regular training series is the same as it was before the auditory stimulus was introduced, *i.e.*, an immediate turn when the pain stimulus was presented, or traversing the whole length of the path into the food-box in the 30 per cent of trials in which no stimulus was given.

The number of animals used, the number of training trials necessary to make the association, and the percentage of correct

responses for Group XIII are given in Table XIV. In the test series only one term of the pair to be associated was presented. These trials would, therefore, not be added to the regular training series in order to secure the number of trials necessary to

TABLE XIV

Rat	Training Trials	Test Trials	% on Last 100
53	140	60	90
54	120	50	92.5
55	140	60	94
56	120	50	91
Average	130	55	91.8

make the association. Their effect would really be expected to hinder the rate of learning, since each time they took the place of a regular day's work, thus making a break in the regular training series. Since each animal completed his work on the test series, the percentage of right response on the last 100 trials, presented in the last column on the table, includes four series (40) of test trials and three (60) of trainnig trials. It was planned to use only the test trials as a basis for this percentage, but since each animal had held a percentage of 90 or above for a period of seven days we were satisfied that the transfer of response was completely made.

From Graph 13 in Fig. 8 the rate at which the association was made can easily be observed. The values in this curve represent the percentages of correct response in the test trials given at the end of the first 40 trials and following each series of 20 trials thereafter. The test series was not introduced in these groups until after the first 40 trials, because it was assumed that not until after then would the transfer of response be sufficiently made to make it worth while to interrupt the regular training series. Since the correct response in the 30 per cent of trials in which no stimulus was given had become thorougly learned in the previous training, mistakes in these trials seldom occurred. Consequently, the percentage records of this group may be expected to begin at 30 and increase to 90 and above as the motor response is transferred to the auditory stimulus. Since the test

trials interpolated after the first 40 training trials show 79 per cent of correct response, it is safe to infer that considerable transfer was made during these 40 trials. The association was readily made; with, in fact, but little more difficulty than was experienced when the two stimuli were presented continuously in the forward direction. This small difference may be due to chance or to the fact that a smaller group was used in these last experiments.

When the animals of Group XIII had learned the association of negative motor response to sound, light was presented in the same temporal relation to sound as sound had been to pain in the previous training, *i.e.*, in immediate succession. By this means it was hoped to get some data on the relative merit of the different stimuli. Table XV depicts the animals used, the number of trials necessary to master the problem, and the percentage of right response on the last 100 trials. A comparison of this

TABLE XV

Rat	Training Trials	Test Trials	% on Last 100
53	120	50	92
54	100	40	90
55	120	50	92
56	120	50	91
Average	115	47.5	91.5

table with Table XIV and of Graph 13L in Fig. 8 (the curves for the present group) with Graph 13 of the same figure shows no marked difference between the two—so little, in fact, that we are not warranted in making the statement that it is easier to associate a motor response with light than with sound when all other conditions are constant. It is preferable to account for this small difference on the basis of the effect of transfer of learning.

In Group XIV where the sound was presented one second after the pain (in most cases after the motor response to pain) the conditions were in all other respects the same as those for Group XIII. Under these conditions we hoped to secure data showing the relative difficulty in making the association in the

backward direction when the two members to be associated are presented continuously and when they are presented with an interval of one second between them. The data for this group are given in Table XVI. The last column of this table is mis-

TABLE XVI

Rat	Training Trials	Test Trials	% on Last 100
57	320	70	73
58	340	80	77
59	380	90	68
60	320	70	76
Average	340	77.5	73.5

leading unless it is understood that this last 100 trials include four series (80) of the regular training trials and only two series (20) of the test trials. This is accounted for by the fact that the test trials were interpolated after the first 60 regular trials and after each 20 subsequent trials. This was done because of the apparent slow rate of making the association under these conditions. The rate of increase in the strength of the association can be observed more accurately by reference to Graph 14 in Fig. 8. This curve is constructed on the basis of percentages of correct response on the test trials only. Although all the animals made occasional correct responses to the sound stimulus during the test trials no real learning is observable at the end of 380 training trials. It is to be regretted that the work of this group was not continued, but sickness caused the experiments to close at this point. Yet, several features of the results deserve comment: 1) Measured in terms of the number of trials necessary to make the association function in the backward direction, it is much more difficult to form the association when the terms presented are separated by one second than when they are presented continuously. The animals in the group to which the stimuli were presented continuously learned the association in an average of 130 trials, while those in the former group showed no improvement at the end of 340 trials. With more training the animals of the group might have learned the association, but we have no evidence that they would have done so. 2) Judged upon

the same basis, it is more difficult to learn to associate a motor response with an auditory stimulus when the latter is presented one second after the former has occurred than when it is presented one second prior to the initiation of the motor response. Under the latter condition Group III learned the association on an average of 128.5 trials, while under the former conditions Group XIV failed to make the association, although they had an average of 340 trials. 3) When the stimuli are presented in immediate succession it is more difficult for the association to function in the backward than in the forward direction. To account for the comparative ease with which the animals made the association in the backward direction under these conditions, one may assume that the new stimulus was not associated with the old stimulus. This response and the new stimulus were experienced simultaneously, and association is due to this simultaneity.

Summary:

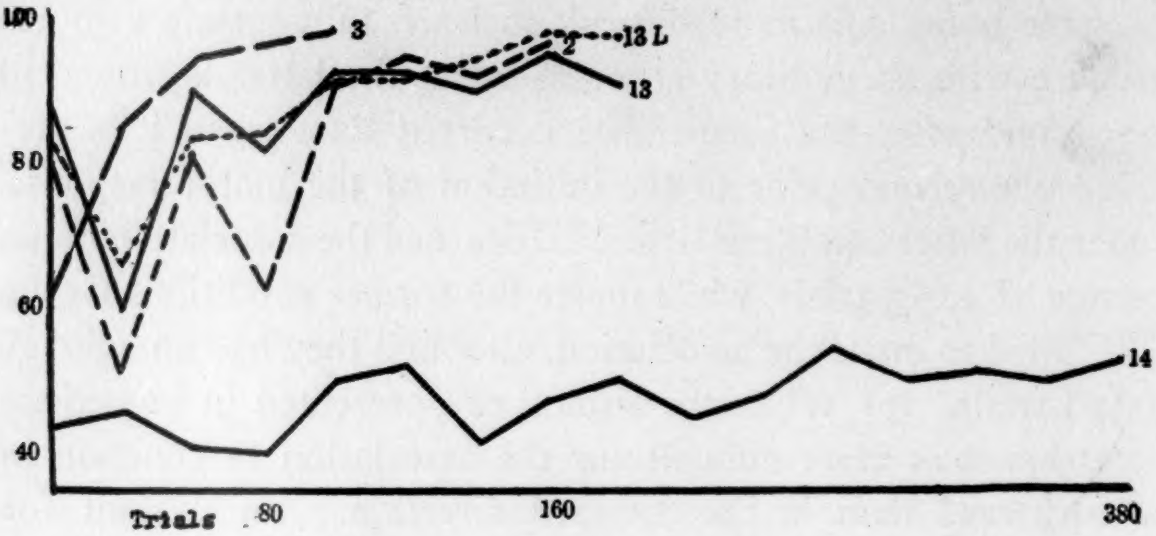
1. Association in the backward direction is only slightly more difficult than in the forward direction when the terms to be associated are presented in immediate succession. This small difference is by no means conclusive.

2. It is much more difficult to learn an association in the backward direction when the terms are separated by one second than when they are presented in immediate succession.

3. It is more difficult to associate a motor response with an auditory stimulus when the latter is presented after the former has occurred than when it is presented before the initiation of the motor response.

4. The data found do not warrant the statement that it is easier to associate a motor response with light than with sound when the stimuli are presented in immediate succession.

2. *Simultaneous and Successive Presentation.*—The present investigation was not undertaken primarily for the purpose of gathering experimental data relating to the well known controversy between simultaneous and successive association advocates, but the condition of our problem made it profitable to do so. Experimental data thus far reported are divided on this



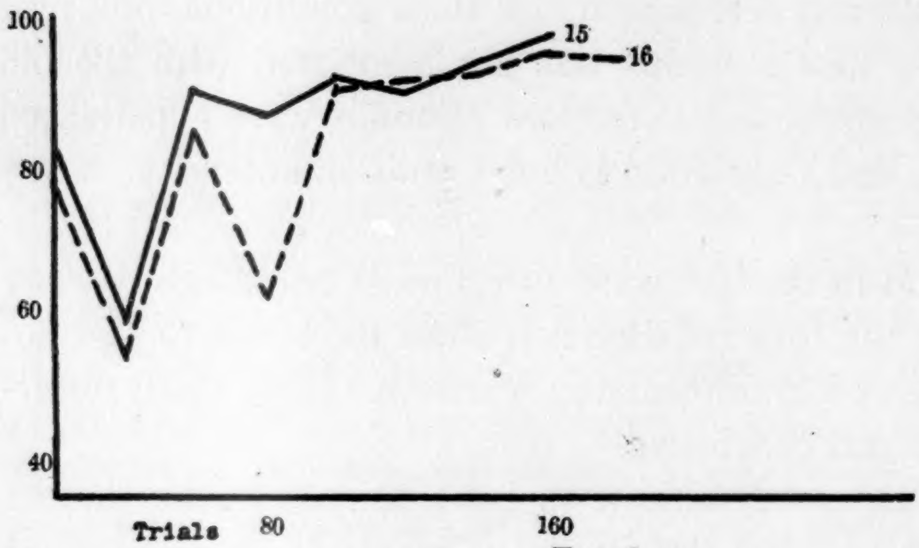


FIG. 8

FIG. 9

In Fig. 8 curves 2 and 3 are reproduced from Fig. 4; curve 13 is the learning curve for Group XIII on sound, and curve 13L is for the same group on light. Curve 14 represents the work of Group XIV. In Fig. 9 curve 15 is the composite curve for simultaneous groups (Groups I and VII); curve 16 is the composite curve for successive groups (Groups II and VIII).

point, but the better controlled experiments report data indicating the superiority of the simultaneous mode. The difference in materials used, experimental conditions, and methods of procedure, no doubt account for the conflicting results. Our data support the superiority of simultaneous presentation. Almost all results thus far reported have come from investigations with human subjects, a fact which gives our data the more significance.

1) Simultaneous Mode of Presentation.—Two groups of animals learned to make the association when the two stimuli were

presented simultaneously. With the one, electric shock and buzzer were used; with the other, electric buzzer and light. The previously discussed test trials were interpolated after each series of 20 training trials in order to check the rate of learning. These tests were not made with Nos. 2 and 9. These continued on the regular learning series until they had had 100 trials before the test series was entered. These animals do not appear to have had any advantage over the other animals of this group where the special tests were entered earlier. These special tests were not expected to assist in learning the association, but they do not appear to have hindered it.

When the pain-buzzer group (Group I) had learned to respond negatively to the first stimulus, pain, buzzer was sounded simultaneously with pain, and the problem was to transfer the negative response from pain over to buzzer. In Table XIV the number of trials necessary to master the problem and the strength of the association are given. The number of test trials given is not shown in this table, but is used in constructing the curve in Fig. 9.

TABLE XIV

Animal	Training Trials	% on Last 100
2	120	91
9	100	96
14	100	91
31	100	91
32	120	90
33	140	92
Average	113.3	91.6

No marked individual differences appear. Although the average number of trials necessary to learn the association is 113.3, in each case where the test trials were given the animal had so completely made the transfer that at the end of 60 trials he made 90 per cent on the test trials. However, because 90 per cent on the last 100 trials had been adopted as a standard, each of the animals was given additional trials on the training series.

The four animals of Group VII had not only learned the negative response to pain, but had transferred this response to

the sound stimulus. After the habitual response to the buzzer had been built up an electric light was presented simultaneously with the buzzer. It was hoped by this means to determine the rate and number of trials necessary to transfer this response from sound over to the simultaneously experienced light. During the first series of 20 trials only a slight disturbance was shown, the average percentage of correct response for the group being 86. The animals continued to respond to the sound but in the presence of light, a rather disturbing factor. The special series of 10 test trials broke down the response. Only 24 per cent above the minimum was made by the group, with two animals falling to 10 per cent above. Table XV contains the individual records.

TABLE XV

Animal	Training Trials	% on Last 100
49	100	93
41	100	96
43	100	91
52	100	92
Average	100	93

At the end of 100 trials each animal had made the association. The transfer again was very rapid, and only a comparatively small number of trials were necessary to make the association.

The learning curves for these two groups, given in Fig. 9 depict the rapid growth of the association. The construction is based on the per cent of right responses in both the regular series and the special test trials. The first and each alternate point thereafter is determined by the average per cent of right response for the group in 20 regular training trials. The other points are the average per cent of efficiency for the group in 10 special test trials. From the curve it is seen that Group VII formed the association by the end of 40 trials, for at no time after this did the percentage of the group fall below 90.

When these two groups are compared there are two points to be noted. 1) In both groups the percentage of right response on the first 20 learning curves is practically the same. In these trials the animals were reacting to an old stimulus but in the presence

of a new one; namely, sound for Group I and light for Group VII. The two stimuli seemed to offer about equal disturbing effect at this point in the learning. 2) When the first special test series was given a complete breakdown occurred in Group VII while Group I only partially broke down. The drop in percentage of right response was from 85 to 55 in the former, and from 84 to 62 in the latter. This breakdown was only temporary, for in the next special series the percentage rose above that of Group I. Light seems to be more difficult in the beginning, but measured on the basis of the required number of trials in the two groups there is little or no difference.

2) Continuous Mode of Presentation.—The work of these two groups (Groups II and VIII) was reported with the other groups on successive association, but in the table below the results are reproduced in order to get a quick comparison of the two modes of presentation. The curves presented in Fig. 9

TABLE XVI

	Trials
Simultaneous	Trials
Group I	113.3
Group VII	100
Continuous	Trials
Group II	120
Group VIII	100

show the different rate of learning the association by the two groups.

With these results before us we are able to observe the following facts: 1) Associations are possible with either the simultaneous or the successive mode of presentation. 2) Our data indicate the superiority of the simultaneous mode of presentation, in that under these conditions the association is more readily made—*i.e.,* fewer trials are necessary to establish it than when the stimuli are presented in succession. 3) The theory that associations are possible only when the terms to be associated are presented simultaneously is not supported by our results.

3. *Learning the Negative Response to Pain.*[1]—All the animals

[1] For method of procedure, one may with profit re-examine the last few pages of Section III above.

used in the experiments of this monograph learned the negative response to pain before beginning work on their respective problems. In training the animals to make this response two mazes were used. With one group of 23 animals the maze shown in Fig. 1 was used; and the maze described by Carr and Freeman in the report of their studies[2] was selected for the training of the latter group. The results of the former group are presented first.

The results for the 23 animals trained on the first mentioned box are given in Table XVII. The first column gives the animal; the second, the number of trials necessary to establish the desired response, and the third the actual number of turns made by each animal before he attained the adopted standard. Since 90 per cent of correct responses must be made within the last 100 trials, it is obvious that few turns were made until near the end of the

TABLE XVII

Animals	Trials	No. of Turns to Pain
1	820	112
2	770	98
4	1015	157
9	745	107
10	684	99
11	890	135
12	901	151
13	1024	136
14	1009	113
16	1079	118
19	753	132
21	715	119
22	914	128
23	803	143
24	926	99
25	1045	123
26	1119	102
27	1134	106
28	937	101
29	1159	160
31	1376	124
32	979	109
33	1251	116
Average	960.6	121.2

[2] *Op. cit.*, p. 466.

training. The number of trials necessary to master this problem varied from 684 for No. 10 to 1376 for No. 31, while the average for the group was 960.6. Since no pain was given in 30 per cent of the trials these animals on the average encountered pain 672 times before learning to make the desired response.

Because of the large number of trials required and the amount of time lost in the long zigzag runways of this box, it was thought expedient to use a simpler box in training the remaining animals. The apparatus used by Carr and Freeman was selected with the hope that time could be saved each day by its use. Future experiments required that the animal be able to hold the standard of correct response in the box presented in this paper and not in the simpler one. It was necessary, therefore, that both apparatus be learned, a necessity which made it seem probable that the group working in the new box would require more trials than the other group. In order to avoid any delay in making the transfer of correct response from one box to the other, the animals were each day given one run in the long maze after having completed the day's work in the short one. In this way the two mazes were learned together: the first being partially learned, then the second partially learned, and finally the first and then the second completely learned. In the light of the findings of Wiltbank[1] this was thought to be the best possible method. Table XVIII gives the number of animals, the number of trials, and the number of turns made by each animal before reaching the required standard of efficiency. The range of trials required is from 394 to 1196; the average for the group of 15 rats is 694.4. Since in 30 per cent of these trials no pain was given, the animals received pain 486 times before learning to respond to it negatively. Not only did this method save time in giving the series from day to day, but on the average it reduced the number of presentations of pain from 672 (the number required for the long-maze groups) to 468—a saving of 204. There are at least three possible explanations of this difference: 1) The increased complexity of the longer box increased the difficulty of the prob-

[1] Wiltbank, R. T., "Transfer of Training in White Rat Upon Various Series of Mazes," *Beb. Mono.*, Vol. IV, 1919.

TABLE XVIII

Animals	Trials	No. of Turns to Pain
35	772	103
37	1196	102
38	787	115
39	817	108
40	429	98
41	840	94
43	578	91
45	651	104
46	679	93
47	394	88
48	652	94
49	585	96
50	654	91
51	614	98
52	768	107
Average	694.4	98.8

lem. The larger number of compartments greatly increased the number of turns and the distance to be traversed in ecah trial, thereby causing confusion. The records show a small number of instances where an animal, after having run the maze for several hundred times, became lost and ran back and forth through three to five adjacent compartments several times before he proceeded to the food-box. 2) With the short box the trials were more frequent than with the long one. It took less than half the time to run the smaller maze; thus, the trials could be given twice as frequently. 3) The getting of food was delayed by the long runways of the larger box. The influence of delaying food, the apparent motive for the animal's effort, is not known, but we are of the opinion that it was an important factor with our animals.

Although the number of trials was reduced when the shorter box was used there was really no difference in the rate of learning between the two groups after learning once began. A study of the learning curves in Fig. 10 confirms the accuracy of this statement. In constructing these curves only the last 500 trials for each animal were used. This was done for two reasons: 1) All observable learning is included in this period. 2) It per-

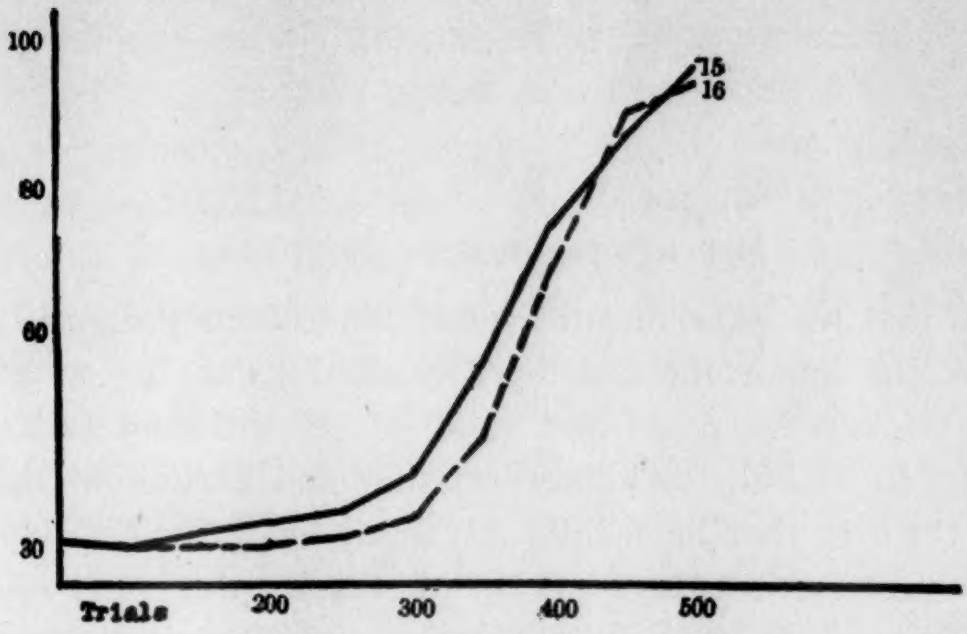


FIG. 10

Curve 15 in Fig. 10 represents the rate of learning in the last 500 trials for groups of animals trained in our maze: Curve 16, the rate for those trained in the Freeman maze.

mits a comparison of the rate of learning at the exact time learning was in progress in the individual cases. This is not possible in either group if the curve is plotted on the basis of trials made from the beginning of the problem, for some completed the training before others showed signs of improvement. In each group there is a period of no apparent learning followed by a short period of rapid learning.

The large number of animals in each of these groups and the almost uniform difference between the number of trials required to master the problem are conclusive evidence that the negative response to pain can be more easily learned in a simple maze than in a more complex one, and that the rate of learning is approximately the same from the time obvious learning first appears until the problem is mastered.

V.

Interpretation of Results

Now that the experimental results have been presented there remains the important task of ascertaining, as far as we can do so, the relative scope and value of the different factors involved. In making this interpretation and evaluation the different theories that have been advanced by the various investigators to account for the experimental results previously reported will be discussed. The following questions set forth the chief points of discussion: 1) How can association be accounted for when the two terms to be associated are presented with a certain time interval between them? 2) How can association be made when the two terms are presented in the reverse order? 3) Is the simultaneous mode of presentation superior to the successive? These questions are considered below in the order given.

1. The nature of the connection established between the two members of a pair of external stimuli, the first member of which is presented for a definite time and is succeeded by the second after a definite interval, is the problem to the solution of which the numerous experimental investigations, beginning with Ebbinghaus and continuing through the past 25 years, have aimed to contribute. Thus far, three theories have been advanced for the explanation of this phenomenon. 1) One may assume the survival of a memory image of the first member of a pair of stimuli during the time interval which separated it from the second stimuli. The second term of the association, then, coincides in time with the "gradually-dying-away" memory image of the first, and it is due to this simultaneity that the association is formed. 2) The connection between the stimuli may be mediated by some third factor which is not only common to the two stimuli, but is also present during the interval which separates them. For example, a series of syllables may be more successfully memorized by associating each syllable with its position in

a temporal sequence. The continued running activity of the animal and the external environment were possible third factors in our experiments. If the running activity, which was almost always present, did serve such a mediating function no increase in difficulty in forming the association over different time intervals should have been evidenced. Nor can this variation among the different groups be accounted for on the basis of the external environment, for it remained constant. 3) The third theory assumes that the two terms may be associated directly, *i.e.*, when the first member of a pair of stimuli ceases the actual nervous excitation is not finished but continues for a time, gradually diminishing in strength. The second member coincides with the diminishing phase of the preceding one, and the association is due to this simultaneity of the two experiences. Although the external stimuli are presented in succession the internal experiences are in a large measure coexistent.

In the light of our data, this "gradually diminishing nervous excitation" continues for at least six seconds. This after-phase may account for the distinct, though disproportionate, increase in difficulty in making the association over larger and larger intervals. If this difficulty in making the association is a measure of the waning strength of the after-phase of the first term, our data warrant the statement that little or no loss in strength is experienced during the first second, but by the end of two seconds a marked weakening is observed. For longer intervals the diminution is gradual with no marked breaks observable. This is in agreement with Froeberg's finding that association can be formed over an interval of at least five seconds.

Although the hypothesis of direct association seems to be the best explanation of successive association, the following possible objections to its acceptance should be pointed out: a) When human subjects are used it may be assumed that all memory and thought connection are not wholly excluded. These connections are many, and some are very difficult to overcome. b) Where activities are interpolated to destroy the memory image of the preceding term it may be assumed that these activities

themselves mediate the association. However, in our experiments with animals these objections are not valid, for few believe that white rats master problems by the use of memory images and concepts. c) A third and perhaps a more vital objection to this theory has been made by Carr; namely, that while one can easily conceive of the persistence of a neural activity for a short interval of time on the principle of inertia, yet the assumption of an indefinite continuance rather taxes one's credulity. For this reason a fourth type of explanation is perhaps the most acceptable. 4) This, the last theory advanced, explains the connection formed between the two stimuli in terms of the decreased resistance of the motor center. The connection is mediated by so decreasing the resistance of the motor center that the one term will become the adequate motor outlet for the nervous impulse aroused by the other. Such a conception is based upon the well known and generally accepted theory of synaptic resistance. The two theories have in common two assumptions: 1) Each sensory impulse tends to follow that motor path which for the time offers the minimum of resistance. 2) The resistance of any center is decreased by an increase in metabolism in that center. If the resistance of one motor center has by continued practice been so reduced that its readiness for response is much greater than that of any other motor outlet, there are no reasons why an effective association cannot be formed over a considerable interval of time.

Since there was no observable third factor mediating the association in our work and since survival of the memory image most likely is not a factor in the behavior of the white rat, there remain but two possible explanations for our results: namely, either the theory of the "akoluthic" phase or the reduced resistance of the motor center.

2. Our discussion has thus far been concerned with the phenomenon of successive association when the two members to be associated were presented in a certain definite temporal relation. We shall now examine successive association when formed under the same conditions except that the order of the presenta-

tion of the terms is reversed. Under these conditions the connection between the terms may be explained upon the same hypothesis as in the experiments in the forward direction. For there is no reason for the assumption that, since the animal has made a certain motor response to the first term, the neural excitation produced by this term suddenly ceases. On the contrary, if the stimulus gets sufficient attention to call out this motor response its neural effect might be expected to diminish more gradually than when no reaction is made to it. The assumption is made here that the "akoluthic" phase diminishes at a rate proportionate to the intensity of the stimulus, which, of course, we have not proved. Although our data are not conclusive on this point they indicate greatly increased difficulty in learning the association when the terms are presented in the backward order. This increase in difficulty may be explained by factors of the situation other than the "akoluthic" phase—factors incident to the reversal of the stimuli. 1) The animal had previously been thoroughly trained to turn when pain was presented. As this response was learned it was easy to observe a change in his behavior from a careless, random run to a slower movement which resembled human behavior when in a state of *expectancy*. This method of approach made him more responsive to any stimulus presented at the time. He, therefore, readily transferred the response from pain to sound when the buzzer was presented before the motor response. If, however, the buzzer was presented after the motor response had occurred this state of "expectancy" was absent, and the transfer of response was more difficult. 2) The previous training had taught the animals that when once turned they must retrace the maze and select the opposite side in order to secure food. Without exception this was true. Hence, after they turned around for pain and started on a *never-failing* road to the food-box, it was scarcely probable that they would proceed in the same state of "expectancy" as before. Daily observations showed that they did not. 3) One may assume that the two terms were associated, but that it was more difficult for them to function in the backward direction. The conditions for learning

here are probably more difficult than in learning the negative response to pain.

3. In most of the experiments reported the problem of successive and simultaneous mode of presentation has been important. In these, successive presentation has been thought of as *immediate* succession of the members of the stimuli. The results are divided as to the better mode of presentation, but the majority of the data favor the simultaneous method. The writer is of the opinion that the difference in results is best accounted for by the difference in the material used in the several experiments and difference in the method of procedure.

The most important point of difference in method of procedure is the attempt to secure an exposure time in successive presentation equal in length to that in simultaneous presentation. If each member of the pair in the successive series is exposed for the same length of time as the pair of simultaneous stimuli the learning time is twice as long in the successive as in the simultaneous presentation. Wohlgemuth felt a necessity for making this exposure time equal in length if comparative data were to be secured. To accomplish this he devised two methods: 1) The exposure time for the simultaneous pair was made twice as long as for each member of the successive pair, the number of presentations remaining the same; 2) The exposure time remained the same while the number of presentations were twice as great in the simultaneous as in the successive pairs. Froeberg objects to both of these methods. To the first his objection is that it "implies that the strength of an association depends upon the *exposure time of the stimuli* only, regardless of whether or not the pair is exposed at the same time, and thus contradicts the theory which was to be proved, namely that association takes place only while the two experiences are present in consciousness." Of the second method his statement is that "it disregards the effect of the distribution of presentations."

The criticism of the second method of equalizing the exposure time is pertinent, but so much cannot be said for the first. This first method is good or bad, depending upon which

phase of the problem is under investigation. If the problem attempts to determine the effect of the exposure time this is a good method, but if the aim is to determine whether or not two terms when presented simultaneously offer greater interference to each other than when presented successively, thereby hindering the process of learning, the method is inept. The method used in our experiments and also by Froeberg is preferable in such investigations. By means of it each term is exposed for an equal time, regardless of the mode of presentation. In simultaneous presentation the exposure time of each of the two terms is not only equal, but the presentations actually coincide in time. In the successive mode the exposure time of each of the terms is also equal, but the presentations succeed each other in time. It is obvious that such a method reveals the relative value of the two modes of presentation on the basis of term interference.

Our data do not indicate term interference when the two terms are presented simultaneously. On the other hand, they indicate a more rapid learning with the simultaneous than with the successive mode. These findings are in agreement with those of Chamberlain, Bigham, Wohlgemuth, and Froeberg, when the latter used nonsense syllables as material.

As indicated above, the results have varied when different materials were used. Disconnected words, associable words, nonsense syllables, syllables, letters, colors, and diagrams have served as materials for the experiments thus far reported in the field of human psychology. From a study of all the results obtained the following conclusion, reached by Froeberg, appears to be true: If the material is such that the pair of stimuli form an organic whole or can be attended as a unit, simultaneous presentation is preferable; if it is such that the materials stand as separate entities, or must be attended to separately in order to be apprehended, successive presentation is preferable.

In the field of Animal Psychology a certain motor response and a definite external stimulus have served as the two terms to be associated. After a motor response to one term is built up the second term is presented in a certain temporal relation to

the first—*i.e.,* either before or during or after the motor response has occurred. In the present experiments light and buzzer were introduced in this way in relation to the motor response, and the results indicate in both instances the superiority of simultaneous presentation. The learning was more rapid when light was used than when sound, but this fact is due rather to transfer of training than to a difference in stimuli.

VI.

Summary and Conclusion

1. The number of trials necessary to learn the association does not increase proportionately with the increase of the time interval between the presentation of sound and pain.

2. Upon the basis of the number of trials necessary to make the association, the difficulty of the problem steadily increases with the increase of the time interval between the presentation of sound and light, but this increase is not proportionate.

3. Our data indicate no marked difference in difficulty for the continuous and one-second interval presentations; likewise, no marked difference is manifest for the intervals above two seconds. The point of disproportionate increase is between one and two seconds.

4. The excess in the number of trials required for the animals to transfer a motor response to sound over the number required to transfer this response to light is perhaps due to the sense material used, yet the transfer of training is an important factor here.

5. Association in the backward direction is very little, if any, more difficult than in the forward direction when the continuous mode of presentation is used. If, however, the two terms to be associated are presented with a time interval of one second between them, the association in the reverse direction is perhaps impossible.

6. Under our experimental conditions and with the sensory material used, our data indicate a slight superiority of the simultaneous mode of presentation. In order to show the relation of our results to those of earlier investigators of simultaneous and successive association, we may classify the findings of the latter upon the basis of exposure time per term. Wohlgemuth (two experiments), Bigham, and Chamberlain used an unequal exposure time per term, the inequality favoring the simultaneous mode, and in every instance they found the simultaneous mode

to be the better. In the experiments of Wohlgemuth (one experiment), Froeberg, and Freeman the exposure time per term was equal, and, except for Froeberg's work with nonsense syllables, all results favor succession as the better mode. Froeberg thinks his exception is not a proof of the superiority of the simultaneous mode, but is rather to be accounted for by the sense material used. Although our results indicate a slight superiority of the simultaneous mode, this is not sufficient to be of great significance. These data seem to warrant the conclusion that when the exposure time per term is unequal the simultaneous mode is the better; when it is equal the better mode of presentation depends upon the materials used.